

## Pedological Investigations of Pleistocene Glacial Drift Surfaces in the Central Yukon

### Recherches pédologiques menées sur des surfaces recouvertes de dépôts glaciaires au centre du Yukon

### Bodenforschungen in den glazialen Oberflächenablagerungen des Pleistozän im Zentrum von Yukon

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Résumé de l'article

On a dégagé les caractéristiques des sols (auxquels on a attribué des noms) dont les morphologies distinctes correspondent à trois épisodes de dépôts glaciaires du Quaternaire. Les propriétés pédologiques qui permettent de faire les distinctions sur le terrain sont la profondeur du solum, la couleur de l'horizon B, le développement des pellicules argileuses, l'altération des éléments grossiers et les caractéristiques périglaciaires. On constate qu'il existe une forte relation entre la teneur en argile en profondeur et l'âge du sol. Les bas taux de Fe et Al extractibles au pyrophosphate par le sodium démontrent l'absence de processus de formation de podzol, même dans les horizons les plus rouges (5YR, 2,5YR). Les paléosols de Wounded Moose sont les sols conservés que l'on peut observer sur les dépôts de la pré-glaciation de Reed (0,2-1,2 Ma) et qui montrent un fort développement de l'horizon enrichi d'argile à cause des couleurs rouges, de la haute teneur en argile et des modifications périglaciaires courantes. Les paléosols de Diversion Creek sont les sols conservés que l'on peut observer sur les dépôts de la glaciation de Reed (8000-12 000 ans) qui montrent un développement moyen de l'horizon enrichi d'argile et qui ressemblent aux luvisols actuels de Gray que l'on trouve dans le sud et le centre des forêts boréales du Canada. Les sols de Stewart sont des brunisols peu développés formés sur les reliefs stables mis en place par les dépôts de la glaciation de McConnell (14 000-30 000 ans). Les paléosols de Wounded Moose et de Diversion Creek, bien que courants à l'échelle locale, n'occupent qu'une faible partie du territoire.

# PEDOLOGICAL INVESTIGATIONS OF PLEISTOCENE GLACIAL DRIFT SURFACES IN THE CENTRAL YUKON

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**ABSTRACT** Distinct soil morphologies associated with three different ages of Quaternary glacial deposits are characterized and subsequently named. Properties which provide a basis for distinguishing these in the field include solum depth, B horizon colour, clay skin development, coarse fragment weathering and periglacial features. A strong relationship is evident between the clay content at depth and the age of soil. Low values of Na pyrophosphate-extractable Fe and Al confirm the absence of any active podzol-forming processes even within the reddest (5YR, 2.5YR) soil horizons. Wounded Moose paleosols are the preserved soils observed on pre-Reid Glaciation (.2-1.2 Ma) deposits which show strong paleoargillic horizon development with red colours, high clay content, and common periglacial modification. Diversion Creek paleosols are the preserved soils found on Reid (80-120 ka) glacial deposits which show moderate paleoargillic horizon development and resemble the contemporary Gray Luvisols of the mid and southern boreal forest regions of Canada. Stewart soils are the weakly developed Brunisols formed on stable landform surfaces of McConnell (14-30 ka) glacial deposits. The Wounded Moose and Diversion Creek paleosols, while found commonly in local areas, occupy only a small proportion of the regional landscape.

**RÉSUMÉ** *Recherches pédologiques menées sur des surfaces recouvertes de dépôts glaciaires au centre du Yukon.* On a dégagé les caractéristiques des sols (auxquels on a attribué des noms) dont les morphologies distinctes correspondent à trois épisodes de dépôts glaciaires du Quaternaire. Les propriétés pédologiques qui permettent de faire les distinctions sur le terrain sont la profondeur du solum, la couleur de l'horizon B, le développement des pellicules argileuses, l'altération des éléments grossiers et les caractéristiques périglaciaires. On constate qu'il existe une forte relation entre la teneur en argile en profondeur et l'âge du sol. Les bas taux de Fe et Al extractibles au pyrophosphate par le sodium démontrent l'absence de processus de formation de podzol, même dans les horizons les plus rouges (5YR, 2.5YR). Les paléosols de Wounded Moose sont les sols conservés que l'on peut observer sur les dépôts de la pré-glaciation de Reid (0,2-1,2 Ma) et qui montrent un fort développement de l'horizon enrichi d'argile à cause des couleurs rouges, de la haute teneur en argile et des modifications périglaciaires courantes. Les paléosols de Diversion Creek sont les sols conservés que l'on peut observer sur les dépôts de la glaciation de Reid (8000-12 000 ans) qui montrent un développement moyen de l'horizon enrichi d'argile et qui ressemblent aux Luvisols actuels de Gray que l'on trouve dans le sud et le centre des forêts boréales du Canada. Les sols de Stewart sont des brunisols peu développés formés sur les reliefs stables mis en place par les dépôts de la glaciation de McConnell (14 000-30 000 ans). Les paléosols de Wounded Moose et de Diversion Creek, bien que courants à l'échelle locale, n'occupent qu'une faible partie du territoire.

**ZUSAMMENFASSUNG** *Bodenforschungen in den glazialen Oberflächenablagerungen des Pleistozän im Zentrum von Yukon.* Unterschiedliche Bodenmorphologien werden auf drei verschiedene Episoden glazialer Ablagerungen im Quaternär bezogen, charakterisiert und anschließend benannt. Die Eigenschaften, welche eine Basis zur Unterscheidung dieser bei der Feldforschung liefern, sind die Tiefe des Solum, die Farbe des B-Horizonts, die Entwicklung der Lehm-Oberfläche, die Verwitterung grober Fragmente und die periglazialen Charakteristika. Es besteht offensichtlich eine enge Beziehung zwischen dem Lehm-Gehalt in der Tiefe und dem Alter des Erdreichs. Niedrige Werte von mittels Na Pyrophosphat herauslösbarem Fe und Al bestätigen das Fehlen jeglicher aktiver Podsol bildender Prozesse, selbst innerhalb der rötsten Erd-Horizonte (5 YR, 2.5 YR). Die Paleosols von Wounded Moose sind die auf den Ablagerungen der Vor-Reid-Vereisung (.2-1.2 Ma) erhaltenen Böden, welche eine starke Entwicklung des paleo-lehmigen Horizonts aufweisen, mit roten Farben, hohem Lehmgehalt und der üblichen periglazialen Veränderung. Diversion Creek Paleoböden sind die auf glazialen Ablagerungen von Reid (80-120 ka) vorgefundenen erhaltenen Böden, welche eine gemäßigte, paleo-lehmige Horizont-Entwicklung aufweisen und den gegenwärtigen Luvisols von Gray ähneln, die man in der Mitte und im Süden der nördlichen Waldgebiete von Kanada findet. Die Böden von Stewart sind schwach entwickelte Brunisols, die sich auf den festen Oberflächenreliefs der glazialen Ablagerungen von McConnell (14-30 ka) gebildet haben. Die Paleoböden von Wounded Moose und Diversion Creek nehmen nur einen kleinen Teil der regionalen Landschaft ein, obwohl sie auf örtlichem Niveau allgemein zu finden sind.

## INTRODUCTION

During 1983 and 1984 field seasons, Quaternary deposits and the soils developed on them were investigated under a joint project in an area of the central Yukon Territory. The principal objectives were to map the distribution of Quaternary deposits of the area and to characterize and compare soils developed on successive ages of glacial deposits within the region glaciated by the Cordilleran Ice Sheet and successive advances of montane glaciers in the southern Ogilvie Mountains.

A review of the field morphological properties (colour, structure, horizonation, depth of weathering) of these soils and the field techniques used to describe and sample them is given in TARNOCAL *et al.* (1985). Major pedogenic differences between soils, especially in clay mineralogy, have been demonstrated by FOSCOLOS *et al.* (1977) and RUTTER *et al.* (1978). A review of the Quaternary geology and geomorphology of the area is described by HUGHES *et al.* (1972), and HUGHES and VAN EVERDINGEN (1978).

In that part of central Yukon glaciated by the main Cordilleran Ice Sheet, BOSTOCK (1966) inferred four separate glacial advances: Nansen (oldest), Klaza, Reid, and McConnell, with each successive glaciation less extensive than the preceding one. Initial geomorphological field observations indicated that separation of discrete landform and soil morphologies associated with the two oldest glaciations were not possible and these have been combined for this discussion as pre-Reid Glaciation materials.

In this paper some physical and chemical properties of soils correlated with the three ages of materials are presented. Names of the paleosols associated with each are proposed.

## MATERIALS AND METHODS

### SITE SELECTION

Within the study area (NTS map sheets 115P and portions of 116B) we were aware in advance that parent materials were derived from three distinct glaciations: the McConnell (~14-30 ka), Reid (~80-120 ka), and generalized pre-Reid deposits (~0.12-1.2 Ma). Figure 1 illustrates these glacial limits within the study area in the central Yukon.

A high degree of selectivity was needed to obtain adequate representation of each age class because the major objective of the project was to characterize and compare soils. Sites were carefully selected to display both optimum soil profile development (moderately well to well drained conditions) and good subsequent profile preservation (level, undisturbed sites). Degree of preservation is an important consideration in dealing with soils developed on older deposits. For example, during McConnell Glaciation soils formed on Reid-age deposits were subjected to a period of periglacial environment during which solifluction, cryoturbation, wind deflation, and conventional water erosion were all active. Soils developed on pre-Reid materials may have been subjected to one million years of glacial and interglacial climates.

### MATERIALS

At each site representative pedons (three dimensional body of soil) were investigated by digging soil pits measuring 1 m × 2 m in area and up to 2 m in depth. The profiles were described in detail according to the EXPERT COMMITTEE ON SOIL SURVEY (1983) and sampled according to McKEAGUE (1978).

A total of 85 sites were described and sampled over two field seasons. Complete data from two representative pedons from each of the three drift materials are presented for the discussion of soil chemical and physical properties. A total of 27 pedons, selected for ongoing detailed mineralogical and micromorphological studies, were used to prepare a summary of these properties for the uppermost IIB horizons for each are category.

### ANALYTICAL METHODS

The analytical methods used are outlined in a manual edited by SHELDRIK (1984). The methods used are as follows: pH in 0.01M CaCl<sub>2</sub>, total C and total N LECO-600 determinator; extractable Fe and Al by pyrophosphate; particle size distribution by pipette analysis; exchangeable cations by extraction with 2N NaCl; and CaCO<sub>3</sub> equivalent by gravimetric method.

## OBSERVATIONS AND RESULTS

All sites, regardless of age or landform were overlain by loess of presumed late McConnell Glaciation origin. All profiles were composed of at least two parent materials. Soil development likely proceeded under variable thicknesses of loess. The long-term soil record lies within the upper portion of the glacial deposits. The zone of soil weathering is referred to as the solum and its thickness is a measure of the degree of pedogenic alteration. Table I outlines some of these field identifiable solum properties. Materials underlying the surface loess are designated II horizons for being the second parent material within the profile. The relationship between increased soil development and increasing age of deposit is evident based on observations on well preserved landscape surfaces.

### NOMENCLATURE

It is proposed to name the soils (paleosols) and their associated morphologies found on the various deposits in order to avoid confusion with names of the glacial periods themselves. Soils formed on pre-Reid deposits, those exposed to periods of apparent temperate conditions as well as at least two periglacial cycles, exhibit deeply weathered sola (up to 2 m), strong paleoargillic horizons, bright red colours, clay-rich alteration products, and prominent periglacial features (wedges, ventifacts, cryoturbation). These we propose to name Wounded Moose paleosols. They were observed to be best represented on a pre-Reid glaciofluvial terrace near Wounded Moose Dome about 70 km southeast of Dawson City and near the limit of Pleistocene glaciation in central Yukon. (Fig. 1). The term applies to paleosols on all pre-Reid landform surfaces that exhibit these characteristic morphological features. The Wounded Moose paleosols occurs extensively and fairly con-

tinuously in the Tintina Trench between Clear Creek and Flat Creek, and on level mesa-like surfaces in the Willow Hills. It also occurs sporadically on outwash terraces on the lower Klondike River and the Yukon River between the Stewart and Fortymile rivers.

Preserved soils found on Reid-age deposits show well developed morphologies similar to present day soils of the southern boreal and mixed forest zones of Canada. These soils possess paleoargillic horizons of brown colours, moderately weathered sola and occasional periglacial features. These soils weathered initially during the Reid-McConnell

interstadial or Boutellier Interval (HOPKINS, 1982), a period of perhaps 30-40,000 years, and were then impacted by periglacial processes active during the McConnell Glaciation. The best examples of these were found on the Reid terminal moraine near Reid Lakes approximately 65 km west of Mayo (Fig. 1). These we propose to name Diversion Creek paleosols after the nearby tributary to Lake Creek where these soils were described. The term applies to paleosols on Reid-age landforms of both the Cordilleran and Ogilvie Mountains ice sheets in the central Yukon that demonstrate these characteristic soil features. These drifts were observed to show similar soil features (TARNOCAI *et al.*, 1985). Diversion Creek

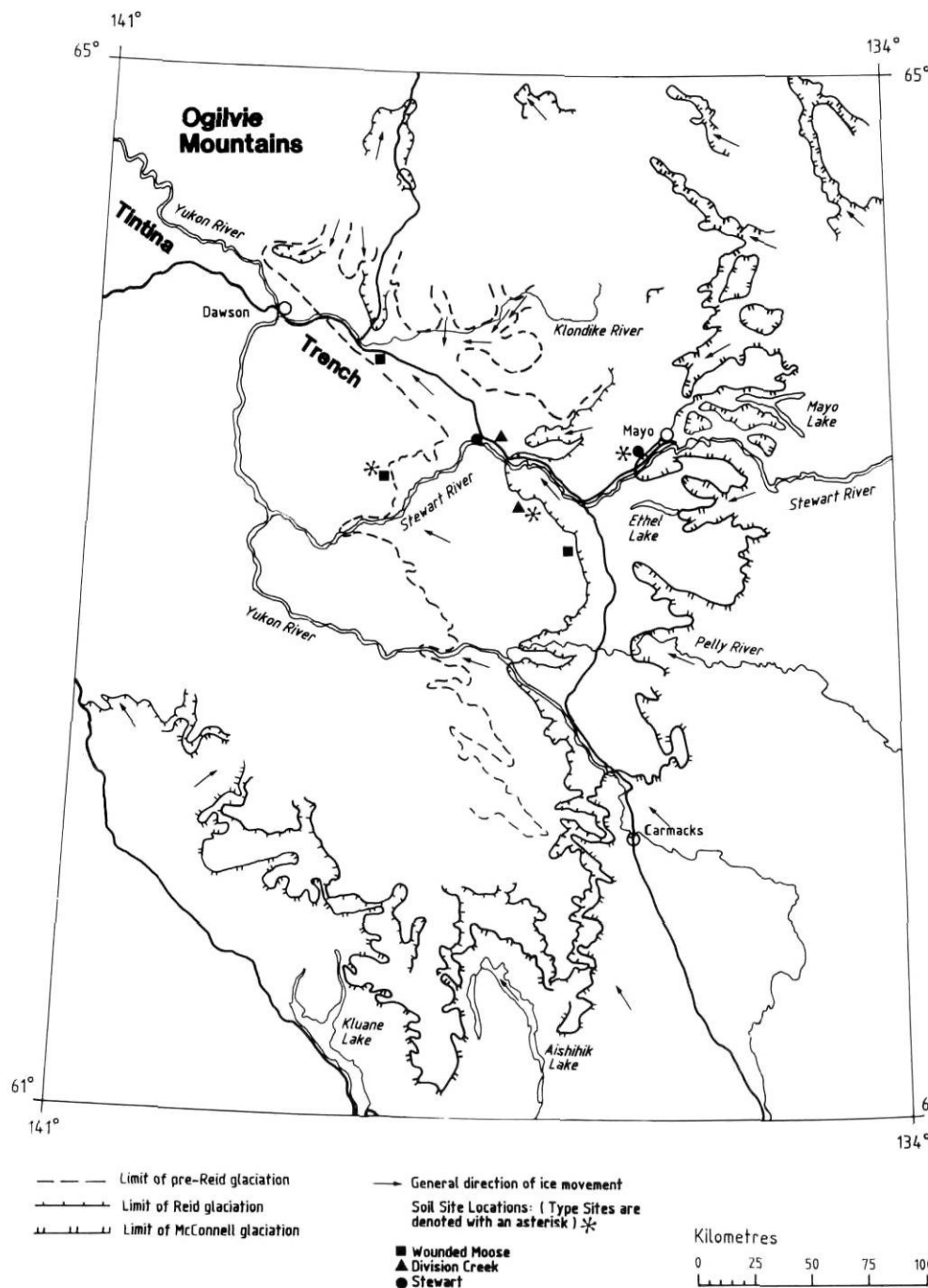


FIGURE 1. Study location and glacial limits in central Yukon. Pedon and type site locations for each paleosol are shown.

Carte de localisation du terrain à l'étude et les limites des avancées glaciaires au centre du Yukon. Pour chacun des paléosols, on donne les localisations du type de sol et des unités de base (pédons).



TABLE I  
Field identification of various surficial materials based on pedon features

Surficial material	Thickness of solum* (cm)	Dominant colour (hue) of		Dominant clay skins	Presence of Cca horizon	Soil classification <sup>o</sup>
		uppermost IIB	lower IIB			
Pre-Reid outwash	109* 205 <sup>+</sup>	5YR	7.5YR	many, moderately thick	not present**	Luvisol (paleo)
Pre-Reid moraine	91 123	7.5YR	7.5YR	many, moderately thick	not present	Luvisol (paleo)
Reid outwash	45 90	7.5YR	10YR	few, very thin	occasionally present	Luvisol (paleo) or Brunisol (paleo)
Reid Moraine	56 106	10YR	10YR	few, thin	not present	Luvisol (paleo)
McConnell drift	21 40	10YR	N/A <sup>++</sup>	none	present	Brunisol

\* mean thickness

\*\* secondary carbonate build-up may occur in the top of the uppermost B horizon due to the leaching of calcareous McConnell loess

<sup>+</sup> maximum thickness observed

<sup>++</sup> there is usually one B horizon

<sup>x</sup> does not include the overlying loess

<sup>o</sup> soil classification according to Canada Soil Survey Committee 1978; the term "paleo" indicate soils whose development began during pre-Holocene times

paleosols occur extensively and fairly continuously on Reid outwash terraces of the Stewart River between Stewart Crossing and McQuesten River and sporadically on upland Reid morainal surfaces.

Stable McConnell drift surfaces exhibit the contemporary soil development of the central Yukon. The area exists under a cold continental climate and belongs to the northernmost portion of the boreal forest region (ROWE, 1972). To facilitate comparisons, soils in similar positions on McConnell landforms where preserved soils on pre-Reid and Reid deposits are found, we propose to call Stewart soils. These are named after the river which forms the major drainage through the study area.

Stewart soils are generally weakly developed and have shallow sola. Portions of the study area have had soil survey conducted and the full range of present surface soil conditions have been described (ROSTAD *et al.*, 1977). Because the Wounded Moose and Diversion Creek paleosols occupy only a small portion of the regional landscape they have largely been missed in the soil survey and ecological survey descriptions of soils of the region.

The use of the term "paleosol" is somewhat peculiar in this instance. The term is used to describe the soil condition on older Quaternary surfaces where soil features are largely attributable to environmental conditions quite different from those at present. However, as these paleomorphologies are found near, or even at, the present soil surface, they are still actively undergoing a certain degree of pedogenic alteration. The term paleosol is used to differentiate these highly weath-

ered forms from the largely unweathered contemporary soils which dominate the landscape of the study area. A summary of paleosol and soil features associated with various ages of parent materials is presented in Table II.

## ANALYTICAL RESULTS

Analytical data for some physical and chemical properties of each soil are in Tables III to V. Information on the site location and classification of the soil to the soil family taxonomic level (CSC, 1978) is given above each profile listing. Data from the type locations for the Diversion Creek and Stewart paleosols are included in Tables IV and V respectively. Data were incomplete for the Wounded Moose paleosol type location. Instead, data are presented from the Flatt Creek profile (Table III) which is similar in all respects to that at the nearby type location. Materials underlying the surface loess veneer are designated as II horizons, III horizons are formed from sand wedge material.

The Wounded Moose and Diversion Creek paleosols developed paleoargillic horizons (IIBt) in which significant increases in clay content have occurred. The remaining horizons are IIBm in which oxidation and leaching have modified the original parent material but significant clay accumulation has not resulted.

Both the sola and parent materials of most soils are strongly acid, in fact the lowest pH reported is for the IIBm horizon formed in McConnell outwash. Carbonate is present in the McConnell morainal deposits throughout the study area and occasionally in deposits of other ages.

*Summary based on field observations of paleosol and soil features associated with various parent materials*

Soil name	Parent material	Rate of weathering in soil	Evidence of cryoturbation in soil	Other periglacial features
Wounded Moose paleosols	Pre-Reid drift	Strong and very strong chemical weathering and disintegration of most rock materials, except quartz and quartzite	Very strong, especially in till; vertically oriented stones; cryoturbated Bt materials	Common to very common sand wedges/involutions; common ventifacts
Diversion Cr. paleosols	Reid drift	Moderate chemical weathering and disintegration of soft rock materials such as porphyry	Moderate; vertically oriented stones; cryoturbated Bt materials, especially in till	Few to very few sand wedges/involutions; common ventifacts
Stewart soil	McConnell drift	Very weak to no chemical weathering on disintegration in rock materials	Very little or none	Not present

*Some chemical and physical properties of Wounded Moose paleosols,  
(those formed on pre-Reid deposits)*

[illegible]

TABLE V

*Some chemical and physical properties of Stewart soils,  
(those formed on McConnell deposits) and their taxonomy*

Horizon	Depth cm	pH (Ca Cl <sub>2</sub> )	%C	%N	Pyro- extractable		Exchangeable cations (meq/100g)					Partial size distribution (%)						Silt	Clay	Texture Class				
												Sand fractions												
																	Sand fractions							
2-1	0.5	0.25	0.25	0.1	0.05	Total																		
mm	mm	mm	mm	mm	mm	Total																		
<i>McConnell outwash near McQuesten airstrip: 63°36'50"N; 137°34'25"W, 440m a.s.l., Orthic Dystric Brunisol, sandy skeletal, mixed, acid, cold subhumid.</i>																								
LFH	4-0	6.7	35.67	1.69	0.01	0.01	87.3	8.6	5.5															
Bm	0-12	4.6	0.10	0.01	0.01	0.02	3.3	0.9	0.1		7.5	10.4	8.7	16.5	19.0	62.2	33.6	4.3	SL					
IIBm	12-28	3.9	1.25	0.07	0.15	0.09	1.9	0.3	0.1	2.8	5.2	17.1	10.8	8.4	5.6	47.1	45.3	7.6	Sil					
IIBc	28-50	4.4	0.33	0.01	0.04	0.04	0.4	0.1	0.1	0.1	29.8	42.8	19.3	3.4	0.7	95.9	1.7	2.4	S					
IIC	50 +	4.5	0.28	0.02	0.05	0.05	0.5	0.1	0.1	0.1	18.9	49.6	25.4	2.9	0.3	97.0	1.1	1.9	S					
<i>McConnell moraine 30 km west of Mayo on Hwy 11: 63°31'23"N, 136°13'16"W, 578m a.s.l. Orthic Eutric Brunisol, sandy skeletal, mixed alkaline, cold humid.</i>																								
L	4-3	5.2	35.2	0.93	0.01	—	52.1	15.7	2.0	—														
F	3-0	5.8	30.2	1.41	0.03	0.04	63.0	8.3	1.2	—														
Bm1	0-4	4.1	1.43	0.06	0.11	0.07	2.6	0.6	0.1	0.5	2.6	4.6	14.8	40.9	13.4	76.2	19.9	3.9	LS					
Bm2	4-9	4.3	0.38	0.01	0.06	0.05	1.5	0.4	0.1	0.2	1.2	3.3	14.0	43.1	17.2	78.7	17.3	4.0	LS					
Bm3	9-14	4.5	0.28	0.01	0.04	0.04	2.0	0.5	0.1	0.2	0.4	3.2	15.2	40.8	12.5	72.0	23.8	4.2	SL					
Bm4	14-21	4.7	0.24	0.00	0.04	0.05	1.6	0.4	0.1	0.1	1.4	5.0	16.6	44.7	16.9	84.5	6.3	9.2	LS					
IIBm	21-38	7.1	0.19	0.00	0.05	0.04	—	—	—	—	7.8	8.5	7.1	16.4	15.5	55.2	37.7	7.0	SL					
IICca	38-90	7.8	—	0.01	0.03	0.02	—	—	—	—	6.4	7.9	7.8	17.6	14.6	54.3	35.5	10.2	SL					
IICk	90-120	7.4	—	0.01	0.03	0.02	—	—	—	—	9.0	10.3	9.7	19.4	15.2	63.5	29.8	6.7	SL					

TABLE IV

*Some chemical and physical properties of Diversion Creek paleosols  
(those formed on Reid-aged deposits) and their taxonomy*

Horizon	Depth cm	pH (Ca Cl <sub>2</sub> )	%C	%N	Pyro- extractable		Exchangeable cations (meq/100g)				Partial size distribution (%)						Silt	Clay	Texture Class
											Sand fractions								
											2-1	0.5	0.25	0.1	0.05	Total			
					%Fe	%Al	Ca	Mg	K	Al	mm	mm	mm	mm	mm				
<i>Reid outwash near the mouth of McQuesten River: 63°34'11"N, 137°25'9"W, 489m. a.s.l. Orthic Eutric Brunisol (paleo), coarse loamy skeletal, mixed, alkakine, cold humid.</i>																			
L	8-3	4.1	42.7	0.92	0.02	—	15.9	13.7	8.4	1.0									
F	3-0	6.5	16.4	0.69	0.01	—	40.0	5.0	1.1	0.4									
Bm1	0-8	5.7	1.32	0.07	0.12	0.06	8.0	1.6	0.1	—	1.6	1.6	0.8	6.6	21.0	31.5	60.4	8.1	SiL
Bm2	8-11	5.9	0.70	0.07	0.05	0.04	6.6	1.4	0.1	—	1.0	1.0	0.8	5.7	23.8	32.4	57.3	10.3	SiL
Btj	11-31	6.1	0.45	0.05	0.05	0.04	5.5	1.7	0.1	—	0.7	1.0	1.8	9.0	19.9	32.4	58.6	9.0	SiL
IIIC	31-61	5.6	0.18	—	0.03	0.02	2.1	0.5	trace	—	0.4	3.4	11.7	43.9	29.6	89.0	9.2	1.8	SL
IIBm	61-100	6.4	0.29	0.01	0.03	0.04	5.8	2.0	0.1	—	10.9	12.0	5.5	9.7	14.9	52.9	37.1	9.9	L-SL
IIBCk	100-120	7.4	0.15	—	0.02	0.03	—		—	—	20.6	21.8	10.7	14.6	12.2	79.9	15.0	5.1	LS
<i>Reid moraine near Reid Lakes: 63°23'04"N, 137°09'22"W, 716m.a.s.l. Orthic Gray Luvisol (paleo), loamy skeletal, mixed, acid, cold humid.</i>																			
L	2-1	6.7	44.8	1.66	—	—	83.3	9.7	2.4	—									
F	1-0	6.6	34.4	1.89	0.02	0.03	75.9	7.9	2.7	—									
Bm	0-6	5.0	1.13	0.06	0.10	0.08	5.8	0.5	0.1	—	2.6	3.7	1.9	5.4	10.0	23.6	68.6	7.8	SiL
BC	6-15	5.0	0.37	0.02	0.06	0.06	5.5	0.7	0.1	—	3.2	3.2	2.2	5.0	14.7	28.4	63.3	8.3	SiL
IIAe	15-19	4.9	0.28	0.00	0.05	0.04	3.3	0.4	0.1	—	11.6	11.6	7.8	14.2	14.7	59.6	34.0	6.0	SL
IIBt	19-35	5.0	0.42	0.01	0.05	0.06	7.3	1.5	0.1	—	8.7	10.6	6.6	11.0	11.8	48.8	33.4	17.8	L
IIBm	35-64	4.3	0.04	0.0	0.05	0.05	4.9	1.3	0.05	0.5	8.3	10.7	4.8	9.7	12.1	45.5	42.7	11.8	L
IIBC	64-94	4.4	0.07	0.0	0.04	0.03	3.0	0.1	0.04	0.1	11.5	15.2	9.2	14.3	14.6	64.6	27.6	7.7	SL
IIC	94-140	4.8	0.06	0.0	0.03	0.02	3.5	0.6	0.04	—	11.3	17.4	10.3	16.9	12.2	68.0	25.5	6.4	SL

All mineral soil horizons have the low carbon and nitrogen values typical of forest soils. Total nitrogen and cation exchange capacities are greatest in the surficial litter horizons (L, F, H). Nutrient cycling in these northern boreal forests occurs largely between these organic horizons and the shallow root systems of covering vegetation. In all cases Ca is the dominant exchange cation, Al becomes exchangeable in the very acid systems.

Sodium pyrophosphate-extractable Fe and Al is very low in all IIB horizons even the very red paleoargillic horizon of the Wounded Moose paleosol. The lack of pyrophosphate-extractable Fe and Al is indicative of the absence of the active translocation of organically-bound forms of these elements although this does not rule out the possibility of the process having been active at some time in the past. Translocation of organically-bound Fe and Al is associated with the processes of Podzol formation. A value of greater than 1% pyrophosphate-extractable Fe and Al is required in the Canadian System (CSCS, 1978) in order to classify a soil as Podzolic.

The surface loess veneers in the region are usually silt loam texture with 55-75% silt in the top mineral horizon. The surficial horizons of the two Stewart soils presented in Table V are composed of coarser eolian materials of variable textures (loamy sand to silt loam) with silt contents ranging from 6-45%. Both sites are located near the present Stewart River floodplain and may have been subjected to deposition of sand size particles rather than silts.

Highest clay contents and relative clay increases are found in the IIBt1 horizons of the Wounded Moose paleosols. Absolute clay values range up to 30% and represent up to ten fold increases over that of the unweathered parent materials. A substantial increase in the clay content of the IIBt1 horizon of the Diversion Creek paleosols formed on Reid moraine is also evident. The absolute clay contents are not as high in the Diversion Creek paleosols as in the Wounded Moose paleosols nor is the depth of Bt horizon development as great (Fig. 2). Stewart soils do not exhibit a similar clay content and depth relationship.

In all cases unweathered parent materials (IIC horizons) tend to be very coarse (i.e. sand or loamy sand). In all horizons, coarse fragments (particles > 2 mm) are common; up to 80% by volume in unweathered outwash, 20-50% in moraines. Occasional stones are observed distributed within the loess veneers.

## DISCUSSION

The most striking feature of the paleosols described in this paper is the presence of well developed paleoargillic (Bt) horizons. Table VI summarizes the routine analysis for the uppermost IIB horizons. All Wounded Moose paleosols and the Diversion Creek paleosols formed on moraine tend to consistently possess argillic horizons. A direct relationship between age and clay content within both morainal and outwash parent materials exists. Carbon content and pH tend to drop with increasing age on the moraines. The outwash parent materials were all acidic and had low carbon contents re-

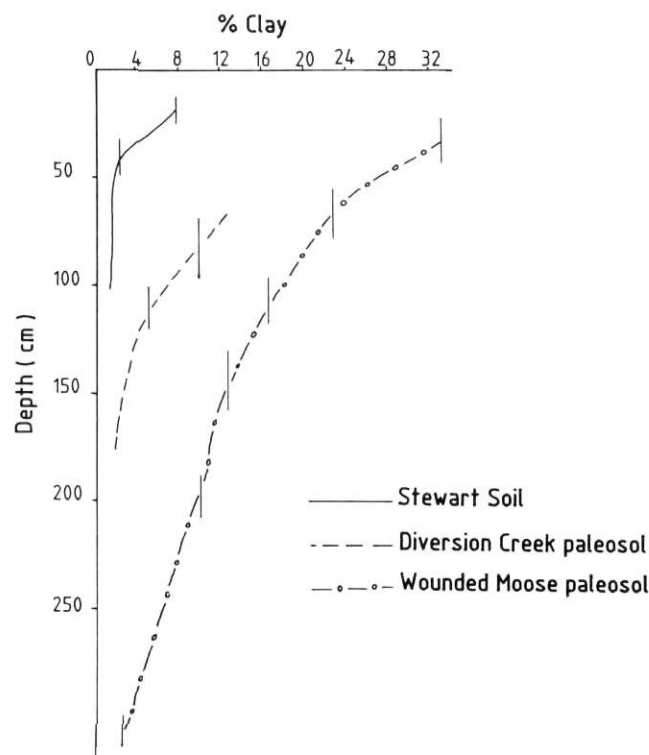


FIGURE 2. Clay distribution with depth for representative soils developed on outwash parent materials. Vertical lines represent depth range from which particle size data are derived.

*Distribution de l'argile selon la profondeur dans les sols développés sur matériau parental d'épandage fluvio-glaciaire. Les lignes verticales représentent l'épaisseur de la tranche d'où proviennent les données sur la taille des particules.*

gardless of age. Pyrophosphate extractable Fe and Al was ineffective as a measure of weathering in these soils.

The best developed paleoargillic horizons occur in the Wounded Moose paleosol where clay loam and sandy clay loam textures are recorded (Table III). This is in strong contrast to the sand and loamy sand textures of the pre-Reid parent materials. Silt and clay values peak in the IIBt1 horizons at the apparent expense of the sand fraction. No examples of former overlying IIAe horizons were observed. These, in whatever form they might have existed, are presumed to have been truncated.

The observed intense oxidation, as seen through very red colours (Table I) and strongly altered clasts in IIBt horizons of the Wounded Moose paleosol, suggests authigenic production of clay sized material *in situ* through the alteration of ferromagnesian and feldspathic materials. This is a process not widely recognized for Luvisolic soils in Canada (KODAMA, 1979). The interaction of this largely amorphous material with inherited phyllosilicate minerals could contribute towards the formation of the complex interstratified and integrate minerals reported in these soils by KODAMA *et al.* (1976) and FOSCOLOS *et al.* (1977). Authigenic clay as well as that produced by the physical comminution of larger particles could provide clay-sized materials available for illuviation into the lower solum.



TABLE VI

*Summary of chemical analysis of uppermost IIB horizons from Stewart, Division Creek and Wounded Moose soils*

Soil name	Glacial deposit	Landform	n	Dominant horizon type	pH (0.01M CaCl <sub>2</sub> )	% C	% pyro-ext Fe + al	% clay	Dominant textural class
Stewart soils	McConnell	outwash moraine	2	Bm	4.8	0.21	0.11	2.1	S
			5	Bm	6.3	0.50	0.11	11.7	SL
Diversion Creek paleosols	Reid	outwash moraine	3	Bm	5.2	0.21	0.08	10.8	SL
			7	Bt	4.7	0.31	0.12	13.7	L-SL
Wounded Moose paleosols	Pre-Reid	outwash moraine	6	Bt	4.8	0.28	0.11	22.6	SL
			4	Bt	4.5	0.20	0.11	20.2	L

Clast weathering was an obvious feature easily observed in the field. The older the soil the greater the proportion of silicious rock (quartz, quartzite and chert) fragments relative to the more easily weathered rock types. Ghosts of feldspathic clasts were common in Wounded Moose paleosol but were not observed in younger soils. Acidic, coarse textured materials provide a medium with minimal buffering capacity thereby facilitating leaching and geochemical weathering. No trend in pH with depth was observed in the Wounded Moose paleosol. Karlstrom (pers. comm.) reports similar soil forms within pre-Wisconsinan drift along the eastern margin of Glacier-Waterton Parks on the Alberta-Montana border.

The Diversion Creek soils being younger show more complete profile preservation and their genesis is more easily inferred. A well developed increase in clay is evident, similar in scale and morphology to the Luvisolic soils elsewhere in Canada. Diversion Creek paleosols are much more developed than the Stewart soils formed on McConnell Glaciation drift. The preservation of the II<sub>Ae</sub> horizon infers an illuvial nature to the clays accumulated within the IIB<sub>t</sub> horizons (Table IV). The unweathered sandy loam Reid morainal parent materials is strongly acid, as is the entire solum of the Diversion Creek paleosol profile presented in Table IV. A slight increase in organic carbon within the IIB<sub>t</sub> is consistent with the process of lessivage as reported by HOWITT and PAWLUK (1985). Similar increases in pyrophosphate-extractable Fe and Al are not observed.

The Diversion Creek soil formed on outwash shows less textural evidence of lessivage than the morainal example. Carbonates are present in this system and the pedon sampled and described includes a prominent sand wedge (IIIC horizon) which dominates the upper portion of the solum. There are some structural features implicit of B<sub>t</sub> horizonation (visible clay skins, moderate subangular blocky structure) but the clay content of the IIB<sub>t</sub>, while more than the underlying IIBC horizon, is the same (~10%) as found in the loess materials at this site. In a nearby swale, thick accumulations of unweathered loess are calcareous. The upper horizons of this profile must have been leached and this carbonate translocated into the

lower solum. It is interesting to note that the B<sub>t</sub> has the lowest pH of any horizons.

The Stewart soil presented in Table V shows, in the case of McConnell outwash, acid pH but weak weathering within this unbuffered medium. The morainal parent material is regionally calcareous and as such, the soil reaction is alkaline (pH 7.8 in IIC<sub>ca</sub>). This is in sharp contrast to the overlying sandy eolian materials with pH between 4.1 and 4.7. There appears to have been little alteration of soil materials underlying this surface veneer.

In Figure 2 the relationship between clay content and depth is plotted for representative profiles in outwash materials. The magnitude of difference between the Wounded Moose, and Diversion Creek paleosols, and the Holocene development of the Stewart soils is well illustrated.

## CONCLUSIONS

The very strong pedogenic development of the Wounded Moose paleosol indicates its formation must have occurred under a relatively warm, moist climate. This conclusion on paleoenvironment had been reached by previous workers (RUTTER *et al.*, 1978) based on pedological observations. The degree of clast alteration and the depth of weathering are both as great as any seen in contemporary soils even in southern Canada. RAMPTON, (1982) reports that the tree line extended to at least the Yukon Coastal Plain in pre-Wisconsinan time. This coincides with our conclusion that much more temperate conditions must have existed in central Yukon for some period of time following the last pre-Reid glaciation.

Paleoclimate inferences drawn from the Diversion Creek paleosol for the Boutellier Interval are less dramatic. The well preserved Luvisolic profile observed on the Reid terminal moraine at Reid Lakes is representative of a soil formed under a climate associated with mid to southern boreal forest. Our conclusion is that the climate during this time had to be warmer and somewhat moister than present conditions.

The present climatic conditions are conducive to the formation of Brunisolic soils (such as the Stewart soil) which are much less pedogenically developed than either of the paleosol morphologies observed on older Quaternary surfaces of central Yukon.

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